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Understanding public perceptions of biotechnology through the "Integrative Worldview Framework"

Annick De Witt, Patricia Osseweijer and Robin Pierce
Delft University of Technology, The Netherlands

Abstract

Biotechnological innovations prompt a range of societal responses that demand understanding. Research has shown such responses are shaped by individuals' cultural *worldviews*. We aim to demonstrate how the *Integrative Worldview Framework* (IWF) can be used for analyzing perceptions of biotechnology, by reviewing (1) research on public perceptions of biotechnology and (2) analyses of the stakeholder-debate on the bio-based economy, using the *Integrative Worldview Framework* (IWF) as analytical lens. This framework operationalizes the concept of worldview and distinguishes between *traditional, modern*, and *postmodern worldviews*, among others. Applied to these literatures, this framework illuminates how these worldviews underlie major societal responses, thereby providing a unifying understanding of the literature on perceptions of biotechnology. We conclude the IWF has relevance for informing research on perceptions of socio-technical changes, generating insight into the paradigmatic gaps in social science, and facilitating reflexive and inclusive policy-making and debates on these timely issues.

Keywords

biotechnology, ethics, GM food, public understanding of science, risk attitudes, science attitudes and perceptions

1. Introduction

Biotechnological innovations stir a range of frequently conflicting societal responses, as different groups assess risks, benefits, desirability, and necessity of new technologies in disparate ways. This tends to lead to cultural polarization and even political, legal, and/or economic gridlock, as seen around genetic modification (GM) of food (agricultural biotechnology), bio-based products such as biofuels (industrial biotechnology), and pharmaceuticals such as vaccinations (medical

Corresponding author:
Annick De Witt, Section Biotechnology and Society, Department of Biotechnology, Delft University of Technology, Julianalaan 67, 2628 BC Delft, The Netherlands.
Email: a.dewitt@tudelft.nl

biotechnology). Although some contestation over societal decisions is generally constructive, and potentially even essential for optimal decision-making, addressing the major challenges facing humanity demands collective action. In the words of Hofstede (1984), "The survival of mankind will depend to a large extent on the ability of people who think differently to act together. International collaboration presupposes some understanding of where others' thinking differs from ours" (p. xv).

Polarization over issues like climate change, nuclear waste disposal, and GM-foods are rarely resolved through more scientific data, as fundamental differences in value and paradigm are at play, also in (the perception of) scientific disputes (see, for example, Hansen, 2013; Kahan et al., 2011; Sarewitz, 2004). Individuals tend to evaluate findings of science and potential risks and benefits associated with emerging technologies differently because they are operating from different *worldviews*—that is, from fundamentally different assumptions about what is real (ontology), how one can know (epistemology), what is of value (axiology), the nature and role of humans (anthropology), and how society should be organized (societal vision/social imaginary).[1] Worldviews have been defined as "overarching systems of meaning and meaning-making that profoundly inform how humans interpret, enact, and co-create reality" (Hedlund-de Witt, 2013c: 156). For advancing "hot" societal debates such as about the emerging "bio-based" economy, understanding cultural worldviews is essential.

The literature has established a wide range of socio-psychological determinants of acceptance of technologies—such as perceived risk, perceived benefit, trust, knowledge, individual differences, and attitudes (see Gupta et al., 2012). Currently, *Cultural Cognition Theory* (CCT) is probably the most widely used conceptual framework for explaining the variance in public perceptions of the risks posed by technologies (Kahan et al., 2009, 2010). Empirical support for these patterns of risk perception includes findings that cultural worldviews explain variance more powerfully than socio-economic status, education, and political ideology, and can interact with and reinforce the effect of related sources of identity such as race and gender (Kahan et al., 2010). CCT builds on Mary Douglas' and Aaron Wildavsky's *Cultural Theory* (1982), which attributes political conflict over environmental and technological risks to a struggle between adherents of competing "worldviews" associated with the group–grid scheme. That is, between an egalitarian, collectivist (low grid, high group) way of life, gravitating toward fear of environmental disaster as a justification for restricting commercial behavior (seen as inequality producing), and more individualistic and hierarchical (low group, high grid) ones, which resist claims of environmental risk in order to shield private orderings from interference, defending established elites. Thus, as Kahan et al. (2009) explain,

> Cultural cognition refers to the tendency of people to base their factual beliefs about the risks and benefits of a putatively dangerous activity on their cultural appraisals of these activities. From a psychological point of view it is easier to believe that behaviour one finds noble is socially beneficial, and that behaviour one finds debased is dangerous, than vice versa. (p. 87)

While CCT has been successful in explaining attitude polarization on climate change and nuclear power (Kahan et al., 2011, 2012), with respect to attitudes toward GM-foods, only mild differences between individuals espousing different CCT worldviews were found.[2] Also regarding vaccinations, CCT may fall short of adequately explaining the different positions,[3] as objectors appear to have very diverse arguments for eschewing vaccinations, ranging from religious arguments and rejection of government overreach in the name of individual freedom, to appraising risks based on a "holistic" understanding of body and mind and distrust grounded in the view that mainstream medicine is too entangled with the (profit-driven) pharmaceutical industry.[4] Politically

speaking, opposition to biotechnological applications frequently proceeds from both "right" and "left" (e.g. Nielsen et al., 2002). In these debates, conflicting ideas about humanity's relationship with nature tend to be central, and arguments about intervention in nature on the level of DNA being "unnatural" and/or "morally inappropriate" loom large in these debates (see, for example, Dragojlovic and Einsiedel, 2012; Finucane and Holup, 2005; Frewer et al., 1997; Gupta et al., 2012; Shaw, 2002). Such objections are found among both conservatives and progressives, and cannot be reduced to merely hierarchical-individualists versus egalitarian-communitarian worldviews.

In our eyes, CCT neither adequately account for these fundamentally different understandings of nature, humanity, and the relationship between them, nor for other aspects of worldviews. Looking at the Likert-type items formulated to measure their worldview-dimensions (see, for example, Kahan et al., 2007), it is noteworthy that virtually all items address questions with respect to individuals' societal visions, while almost entirely omitting questions addressing other worldview-aspects, such as views on nature, reality at large, God/the divine, science and other ways of knowing, the nature of the human being, and the most important values in life. In light of the centrality of issues such as "naturalness" and "playing God" in the biotechnology debate, these absences may explain CCT's limited effectiveness in accounting for attitude polarization with respect to certain biotechnological applications.[5] A related weakness is CCT's predominant focus on risk perception; authors like Felt and Wynne (2007) have warned of the tendency to reduce the meaning of public unease with new technologies to questions of "risk" and safety. Instead, they argue, we should appreciate public concerns that question technology's social purposes or suggest alternatives to technological innovations, such as lifestyle changes.

To satisfactorily explain the complexity of positions, argumentation, and controversy surrounding biotechnological innovation, a broader conception of "worldview" is needed that includes aspects such as ontology, epistemology, and axiology. In this article, we therefore aim to demonstrate how the *Integrative Worldview Framework* (IWF; see Hedlund-de Witt, 2013b, 2014a) can be used for analyzing societal responses to biotechnological innovation more effectively. We do this by (1) reviewing research on public perceptions of biotechnology, and (2) reviewing academic analyses of the stakeholder-debate on the emerging "bio-based economy," using the IWF as analytical lens. The IWF operationalizes the concept of worldview into five aspects—*ontology, epistemology, axiology, anthropology*, and *societal vision*—and distinguishes between four ideal-typical worldviews: *traditional, modern, postmodern*, and *integrative*. We pass over the integrative worldview (e.g., Hedlund-de Witt, 2014b), as it is newly emerging, therefore more speculative and less researched, and, more importantly, appears less clearly in current debates about biotechnology.

There are numerous portrayals of what a bio-based economy or *bio-economy* is or should be (McCormick and Kautto, 2013). It can be understood as a political vision and ideal of an economy based on renewable, biologically derived materials for the production of food, feed, materials, chemicals, pharmaceuticals, and energy. Biotechnology is central in its development, as genetic engineering is often used to convert sugars into biomass for the production of added-value products. While agricultural biotechnology may be deployed for the production of crops with specific characteristics, such as drought or herbicide resistance, there is no consensus on the inclusion of all bio-based production in a bio-economy, as is the case with genetically modified crops for *food* purposes (Koppejan and Van Est, 2011). Although biotechnology and the bio-economy vision are not interchangeable, the inevitable relationship between the two justifies linking them in this study.

When studying public interaction with biotechnological innovation, the main value of the IWF is that it provides a unifying framework that can advance our conceptual understanding of the vast and heterogeneous literature on public perceptions of biotechnology: the framework may enable us to collate insights from earlier research, and synthesize some of the reported socio-psychological

determinants of the public's interaction with biotechnological innovation. Earlier research using the IWF has demonstrated its usefulness for understanding the relationship between worldviews and the sustainability of individuals' lifestyles, both conceptually (Hedlund-de Witt, 2012) and empirically (Hedlund-de Witt et al., 2014). Since the IWF illuminates overarching *systems* of meaning and meaning-making, it may explain why certain individuals tend to emphasize benefits while others emphasize risks, and why some trust information provided by science while others rely on information provided by societal or religious organizations. Moreover, using the ideal-types of traditional, modern, and postmodern worldviews allows us to connect societal responses to biotechnology with cultural trends, as well as with the historical-developmental trajectory of cultural epochs and worldviews in the West, described by philosophers of Western thought, historians, and social scientists (e.g. Giddens, 2009; Inglehart, 1997; Inglehart and Welzel, 2005; Tarnas, 1991; Taylor, 1989). This encourages a larger understanding of the cultural-historical context of societal views on biotechnology, and supports interdisciplinary research efforts.

In the next section, we explain our methodology. The IWF is applied to the literature on public perceptions of biotechnology in the section "Public perceptions of biotechnology." In the section "Stakeholder perspectives on the bio-economy" the IWF is applied to the literature analyzing a variety of stakeholder-positions vis-à-vis the bio-economy. We finish in the "Discussion and conclusion" section.

Methodology

The IWF (see Hedlund-de Witt, 2013c, 2014a) is an interdisciplinary framework that synthesizes research from sociology, environmental psychology, and developmental-structural psychology, aiming to support the understanding of different worldviews at play in contemporary societal dynamics and debates. It operationalizes worldviews as consisting of (at least) five interrelated, constitutive aspects and distinguishes between ideal-typical worldviews, including a traditional, modern, and postmodern worldview. Here, we use the IWF as a heuristic tool for ideal-typically analyzing existing research on public and stakeholder-perceptions vis-à-vis biotechnology.

Five aspects of worldviews

Ontology is a perspective on the nature of reality, answering questions such as: What is nature? How did the universe come about? *Epistemology* is a perspective on how knowledge of reality can come about, and answers questions such as: How can we know what is real? What is valid knowledge, and what is not? An *axiology* is a perspective on what a "good life" is, in terms of morals and quality of life, ethical and esthetic values, answering questions such as: What kind of life has quality and gives fulfillment? What is life all about? *Anthropology* is a perspective on who the human being is, and answers questions such as: What is the nature of the human being? What is his role and purpose in existence? Lastly, a *societal vision* or social imaginary is a perspective on how society should be organized and how societal problems and issues should be addressed. It answers questions such as: What is the role of technology in addressing our issues?[6]

The IWF uses these five aspects to systematically and comprehensively analyze worldviews, distinguishing between *ideal-typical* worldviews (Table 1). These worldviews are logically constructed models to help analyze the real world, idea-constructs that help put the seeming chaos of social reality in order. They do not claim validity in terms of an uncomplicated correspondence with social reality, but function as analytical tools. Ideal-types represent "ideal" or "pure" types, and in reality are expected to be found in combination (Campbell, 2007).

Table 1. The IWF ideal-typically constructs traditional, modern, and postmodern worldviews, using the five worldview-aspects as organizing scheme (see Hedlund-de Witt, 2013b; De Witt and Hedlund, 2015, in press).

	Traditional worldview	Modern worldview	Postmodern worldview
Ontology	Religious/metaphysical monism. Reality as singular, transcendent.	Secular materialism. Reality as singular, immanent.	Post-materialism. Reality as pluralistic, perspectival, constructed.
	Universe as purposively constructed whole. God-created universe *ex nihilo*.	Mechanistic universe brought about by random mutation and natural selection.	Cosmogony as cultural construct?
	Transcendent God is separate from profane world; dualism	Material reality devoid of meaning, intentionality, consciousness; dualism, disenchantment.	Reality as discontinuous and fragmented; anti-essentialism.
	Nature as embodiment of meaningful, imposed order (e.g. God's creation).	Nature as instrumental, devoid of intrinsic meaning and purpose. Resource for exploitation	Nature as constructed through a plurality of cultural values, meanings, and interests
Epistemology	Naïve realism; emphasis on concrete-literal interpretations of religious doctrine (literalism, dogmatism).	(Post-)positivism; emphasis on reality as objectively knowable (empiricism, reductionism, scientism).	Social constructivism; emphasis on reality as constructed, perspectival (pluralism, relativism).
	Religious authority (scripture, divine revelation, tradition).	Secular authority (science, the state).	Internalization of authority (e.g. moral, emotional, intuitive, artistic knowing)
	A-methodological	Quantitative methods, methodological monism.	Qualitative methods; methodological pluralism
	Substantive rationality	Procedural rationality	Skeptical rationality?
Axiology	Traditional values (e.g. security, tradition, conformity, obedience, humility)	Rational-secular, materialist values (e.g. power, achievement, hedonism, stimulation)	Self-expression, post-materialist values (e.g. openness to change, self-direction)
	Emphasis on community, family	Emphasis on independent individuality	Emphasis on unique individuality
	Pre-conventional morality?	Conventional morality?	Postconventional morality?
Anthropology	Humanity in managerial stewardship role vis-à-vis nature	Humanity in promethean control over nature	Humanity in cautious relationship to nature
	Prime purposes determined by larger order and social roles. Human being as sinful/fallen from grace. Dependent on religious/ metaphysical authorities for salvation.	Prime purposes of a material, hedonistic nature. Human being as self-optimizing, independent being. *Homo economicus.*	Prime purposes are found within, intrinsic. Human being as self-expressing, unique individual.
	Ethno-centric identity?	Socio-centric identity?	World-centric identity?
Societal vision/ socio-technical imaginary	Traditional societies, emphasis on (subsistence) farming.	Industrial societies, emphasis on industry and commercial industrial agriculture.	Post-industrial societies, emphasis on service economy and creative industries.
	Traditional and religious authorities and values are looked at for solutions to societal and environmental problems.	Technological optimism: science and technology will solve societal and environmental problems.	Skepticism, idealism: emancipation of marginalized voices through "deconstructing" discourses and revealing power dynamics will solve societal and environmental problems

Three ideal-typical worldviews

In *traditional worldviews*, the religious sphere is generally not distinguished from the secular sphere, nor is metaphysics from science (Hedlund-de Witt, 2013b, 2014a). Religious or metaphysical views on reality answer the big questions, and generally substantial faith is placed in religious authorities, such as scriptures, doctrines, and leaders. In this worldview, a transcendent God is usually seen as separate from the profane, earthly world, man as fundamentally different from nature. The relationship with nature is frequently understood in terms of "dominion" or "stewardship." Traditional worldviews emphasize the importance of family and community, and values such as sobriety, discipline, solidarity, respect for tradition, humility, sacrifice, and austerity.

Modern worldviews attempt to achieve liberation from oppressive, frequently religious, authorities and understandings of the past. The vision of reality is secular and materialistic: the existence of a higher power or intangible dimension is generally rejected. Science tends to be seen as the ultimate source of reliable knowledge, providing access to objective reality. This "objectification" generates a dualism between object and subject, which has led to immense scientific, technological, and economic progress as well as to an instrumentalization of nature. Science and technology are seen as pathways to progress, and central means to address humanity's most pressing issues. Reason is of paramount importance. The autonomous, "self-made" individual has a central position in this worldview. Individualistic and hedonistic values—such as freedom, success, and pleasure—are usually dominant.

Postmodern worldviews are characterized by a tendency to acknowledge and value multiple perspectives on reality, and generally question science's claim to exclusively provide objective knowledge. This worldview instead emphasizes the relativity and contextuality of knowledge, and the value of moral, emotional, and artistic ways of knowing. Frequently, a critical attitude toward the modern model of society (e.g. its materialism, individualism, dualism, reductionism) is observed, and emancipation of marginalized and oppressed groups is a central motivation. This is reflected in the rise of social movements since the 1960s, promoting peace, multiculturalism, women and gay rights, and the environment. Generally, postmodern worldviews celebrate diversity, relativism, and "post-materialistic" or "self-expression" values such as authenticity, imagination, and intuition.

For reviewing research on public perceptions of biotechnology, data were readily available, including large-scale, cross-culturally conducted surveys, such as the *Eurobarometers on the Life Sciences and Biotechnology* (see, e.g., Gaskell et al., 2006, 2010) and the *World Values Surveys* (e.g. Leiserowitz et al., 2006; Simon, 2010). We focused on studies exploring public attitudes toward forms of biotechnology, including industrial and agricultural. In addition, we felt our analysis would benefit from more qualitative insights. We therefore reviewed academic analyses of the debate on the emerging bio-based economy, as these tend to carefully unpack stakeholders' arguments, displaying underlying reasoning and paradigmatic assumptions. We used multiple studies analyzing stakeholder-positions (e.g. Kornerup Bang et al., 2009; Levidow et al., 2012a; Schmid et al., 2012), which frequently base themselves on major policy-documents such as the 2000 Lisbon Strategy, the 7th Framework Programme for Research and Technological Development (FP7) of the European Commission, and publications of the Organisation for Economic Co-operation and Development (OECD), as well as documents of for example societal organizations such as the World Wide Fund (WWF) and the ETC Group. Although a comprehensive review of both bodies of the literature is beyond the scope of the article, we included studies based on large multinational samples, as well as review-articles, intending to offer a broad, generalizing analysis of this material. Both bodies of literature were analyzed using the IWF as heuristic, probing for the five aspects that worldviews comprise, and comparing results with the three major ideal-typical worldviews.

Public perceptions of biotechnology

Several studies suggest that the positions of the larger public toward industrial biotechnology can be understood in terms of larger cultural patterns or worldviews. For example, in a European-wide study using the data of the 1996 Eurobarometer survey, two different patterns of resistance against biotechnology were found, which the authors characterized as "traditional" and "modern" skepticism, based on fundamentally different values and concerns:

> The typical representative of the "traditionalist" group is older and will have completed his/her education after primary school rather than attending university like the typical "modern." The traditional group also has an inferior knowledge of biotechnology. And where the "traditional" inclines towards the centre and right of the political spectrum, the "modern" is oriented towards the left. Further, the traditional tends to be strongly religious whereas the modern is inclined to be a strong non-believer. Finally, the traditional group may be described as materialists, and the modern as post-materialists. (Nielsen et al., 2002: 184)[7]

The two groups of skeptics were not only characterized by certain demographics (age, education level, residence) but also by political, religious, and value orientations. As the authors argued "modern biotechnology is commonly confronted by both a 'pre'-industrial critique of intervention in 'nature's order', as well as a 'post'-industrial critique of the potential risks involved with the new technology" (Nielsen et al., 2002: 192). While the traditionalists appear to be critical on a principled, *a priori* basis, the moderns demonstrate a more pragmatic orientation, emphasizing that intervention in nature through biotechnology is not reprehensible *per se*, but depends instead on circumstances, such as risks, benefits, and regulations in place. Moreover, results showed that while moderns tend to trust non-governmental organizations (NGOs) such as environmental and consumer organizations, traditionalists are less sure whom to trust, generally placing a higher degree of trust in the medical profession, and in some Catholic countries in religious organizations. Moderns also display a much higher level of active participation in the biotechnology discourse, generally pleading for regulation of the industry, labeling of GM food, and public consultation (Nielsen et al., 2002).

The two "skeptic" groups appeared affiliated with different worldviews. However, while the authors spoke of a "traditional" and "modern" resistance, we think these patterns can be better understood in terms of traditional and *postmodern* (instead of modern) worldviews. This understanding also aligns with some of the authors' own framings, as they state the modern group to be characterized by "postmaterial values," and articulating a "post-industrial" critique with respect to biotechnology. It is also supported by the massive, longitudinal, cross-cultural data of the *World Values Surveys*, which find post-materialist values emerging in post-industrial or postmodern societies, rather than in industrializing or modern societies, which tend to be characterized by a materialist value-orientation (Inglehart, 1997).[8] Also in other respects the characteristics of this skeptical group align better with a postmodern worldview: from their emphasis on uncertainty, systemic impacts, and unpredictability; their trust in non-governmental and societal organizations; their politically left-wing inclination; to their distrust of corporations to take care of societal needs. It appears that because these researchers studied "resistance" against biotechnology rather than different positions with respect to biotechnology (seemingly making acceptance of biotechnology the norm), the ideal-typically "modern" position may have been overlooked. This example thereby illustrates how the IWF advances our understanding of larger, societal currents in the biotechnology debate.

Thus, individuals with a traditional worldview may be skeptical of industrial biotechnology because technological intervention in nature is seen as *a priori* unacceptable,[9] while individuals with a postmodern worldview may be skeptical because nature is conceptualized as a complex, somewhat fragile,

set of systems, which are hard to oversee (Nielsen et al., 2002). In contrast, individuals with a *modern* worldview may have fewer problems with interfering in nature, displaying a "techno-trust" that assumes that environmental problems and other risks will be solved or managed through the development of science and technology (see also Hedlund-de Witt et al., 2014; Koppejan and Asveld, 2011).[10]

Understanding differences in perception of science and (bio)technology, the post-industrialism hypothesis of the public understanding of science appears relevant. This hypothesis states that while in industrial (more modern) societies science and technology tend to be viewed positively and generally hold considerable authority, in post-industrial (more postmodern) societies scientific knowledge becomes more diffuse and contested (Allum et al., 2002). For example, the *1995 World Values Survey* found that although the global public tends to have positive attitudes toward science and technology,[11] support for technology was significantly higher in countries with low gross domestic products (GDPs) than in high-GDP countries, indicating more skepticism in technologically advanced societies. This pattern resonates with our understanding of a "technologically optimist" modern, and "tech-cautious" postmodern worldview.

Results of the *Eurobarometer on the Life Sciences and Biotechnology 2010* revealed a similar pattern. With respect to tackling climate change, respondents across Europe (except in Latvia and Malta) favor changes in ways of living over technological solutions, even if this means reduced economic growth. However, while in Bulgaria, Poland, Estonia, Lithuania, Romania, Latvia, and Malta support for the "changing ways of life" solution was below the 55%, in eight of the wealthier European countries support for changing lifestyles was above 70% (Gaskell et al., 2010). These results indicate that an uncomplicated belief in the "fruits of science" tends to be greater in less industrially advanced (generally modernizing) societies, while caution with respect to certain technologies tends to be higher in post-industrial (more postmodern) societies (see also Inglehart and Welzel, 2005). Allum et al. (2002) found the correlation between knowledge and positive attitudes toward biotechnology to be lower in countries that were closer to the post-industrial ideal-type than in those where the economy was less developed, as the postindustrialisation hypothesis of PUS predicts. The same correlation was observed *within* countries, with substantial differences between the "technological optimism" of peripheral versus urbanized areas. These findings thus also refute the (widely criticized) "deficit-model" of PUS:[12] "The pictures in the capitals of Europe is of citizens at once more knowledgeable about biotechnology but more circumspect in their expectation of what benefits it may bring" (Allum et al., 2002: 239).

Multiple studies have highlighted the apparent difference in opinion about agricultural biotechnology across the Atlantic. Publics in the United States and Canada have tended to be substantially less negatively disposed to GM food than publics in Europe (Gaskell et al., 1999; Peters et al., 2007). Survey research in the United States and Germany showed that *appreciation of nature* was a predictor of negative attitudes toward food biotechnology, explaining differences in attitude towards GM within countries as well as between countries (Peters et al., 2007). For example, US respondents tended to agree more often that "humans are smarter than nature" and less often that "nature should be left alone" and "things in nature are more perfect than those made by humans." As conceptions of nature are a vital part of any worldview, these findings can be understood in the context of the IWF's ideal-typical worldviews. A statement like "humans are smarter than nature" fits into a modern worldview, while the statement "things in nature are more perfect than those made by humans" resonates with a more postmodern understanding of the world. The statement "nature should be left alone" could point to a more traditional or more postmodern worldview, depending on the rationale for leaving nature alone.

Dragojlovic and Einsiedel (2013) showed that the conviction that nature should remain untrammeled is frequently tied to the perception that nature is an intrinsically valuable, even sacred entity. This *sanctification of nature* can be both theistic and nontheistic (Pargament and Mahoney, 2005).

Theistic sanctification tends to be related to explicitly religious beliefs. In qualitative studies, for example, objections to a given GM-technology founded on its "unnaturalness" were shown to often go hand in hand with concerns that scientists are "playing God" (Shaw, 2002: 281). Nontheistic sanctification occurs when individuals perceive objects to possess qualities associated with the divine—e.g., transcendence—even though they may not espouse beliefs in a (traditional) God or higher power (Pargament and Mahoney, 2005). Nonreligious forms of spirituality (at least in a Western context) often involve such a sanctification of nature (Giner and Tábara, 1999; Hedlund-de Witt, 2011, 2013a). While the theistic sanctification of nature resonates with the traditional worldview as described in the IWF, the nontheistic sanctification resonates more with the postmodern (and the integrative) worldview.[13]

Hedlund-de Witt et al. (2014) found empirical correlations between more modern worldviews and an instrumental understanding of nature (expressed in statements like "nature has value only because the human being is able to use and enjoy her") as well as a sense of technological optimism ("through the development of science and technology environmental problems will be solved by themselves"). The study also found correlations between more postmodern worldviews and a sense of "connectedness to nature" (expressed in statements like "I have a deep feeling of connectedness to nature") and more sustainable lifestyles (expressed in self-reported behaviors like meat consumption and political priorities). The traditional worldview appeared to have somewhat different tendencies, seemingly taking a position between the postmodern—emphasizing connectedness with nature—and the modern—assuming control of an objectified universe and solving environmental issues instrumentally. These results show that conceptions of nature, essential to any worldview, inform individuals' positions on environment and technology in ways that resonate with traditional, modern, and postmodern ideal-types.

Other studies found gender differences in attitudes toward biotechnology (e.g. Kahan et al., 2007; Nielsen et al., 2002; Simon, 2010). Some studies conclude that neither socio-demographics nor differing levels of scientific knowledge could explain females' greater probability of pessimism toward biotechnology; instead these differences may be ascribed to diverging "basic human values" or worldviews (Kahan et al., 2007), with women placing less value on social dominance and displaying different attitudes toward nature (Simon, 2010).

Stakeholder perspectives on the bio-economy

In the debate on the emerging bio-economy, there appear to be two main, competing perspectives (sometimes described as "master-narrative" and "rivaling narrative"; see, for example, Levidow et al., 2012b). The first perspective could, ideal-typically speaking, be characterized as a "*modern*" technologically optimist view, emphasizing the economic and sustainability potential of the bio-economy, and tending to see science and technology as a solution to contemporary crises. The other perspective appears more cautious, critical, and skeptical, emphasizing that commercial interests drive the agenda for the bio-economy, underscoring risks, advocating small-scale, participatory solutions and economies, and speaking up for marginalized voices such as those of developing countries, small farmers, and sensitive ecosystems. This latter view could be characterized as being of a *postmodern* nature.

For example, Levidow et al. (2012a, 2012b) compared divergent socio-technical paradigms of agricultural innovation, distinguishing between a dominant, *genetic engineering and life-sciences* oriented view, and a marginal, *agro-ecological engineering* view. According to these authors, these visions have fundamentally different problem-diagnoses of agro-economic threats. While the industrial vision tends to blame inefficient production methods for the falling behind of the European agro-industry in the global market, the agro-ecological vision problematizes the agro-industrial

monoculture system, which makes farmers dependent on external inputs, undermines their (local, tacit, social) knowledge, and distances consumers from agri-production knowledge. While in the first paradigm the basic techno-scientific vision is to genetically modify plants for greater productivity or new objectives (e.g. nutritional content, new products), the vision in the second paradigm is to design agro-ecological systems that minimize needs for external inputs (e.g. water, fertilizers), instead enhancing ecological interactions. Quality in the first paradigm is characterized by "decomposability of qualities," identifying traits or attributes based on genetic characteristics, which can be extracted, decomposed, and recomposed to create "novel combinations for extra market value" (Levidow et al., 2012a: 4). These ideas about quality demonstrate this paradigm's alignment with the reductionist ("building-block") logic and materialist values of the ideal-typically modern worldview. The second paradigm characterizes quality by "integral product identity via holistic methods," seeking to valorize distinctive, comprehensive qualities socially validated by consumers in various forms (e.g. organic certification, territorial characteristics, farmers markets; Levidow et al., 2012a: 4). These ideas demonstrate this paradigm's alignment with the holistic, systems-logic of the postmodern worldview, as well as its emphasis on postmaterial values and concern for the oppression of certain interest groups.

Schmid et al. (2012) argue similarly that there are two competing views vis-à-vis the bio-economy promoting different futures for agricultural systems and farmers' futures: an industrial and a public goods perspective. The *industrial* perspective is largely driven by the OECD, high-level policy-makers in the European Union and United States, multinational companies, and the life-sciences, and tends to benefit capital-intensive industries at higher levels of the value chain. A *public goods* perspective in contrast emphasizes "agro-ecological methods, organic and low (external) input farming systems, ecosystem services, social innovation in multi-stakeholder collective practices and joint production of knowledge" (p. 47). In the industrial vision, large-scale production of biomass, resource efficiency, the creation of novel products, and competition in global markets is emphasized. Innovation and knowledge-generation—especially of the life sciences—is central. However, the importance of local knowledge and capabilities to better accommodate diversity and complexity is rarely mentioned in this vision (p. 52). The agro-ecological view in contrast emphasizes a more integrated, holistic understanding in which "multi-stakeholder partnerships involving a broad range of civil society groups, including farmers, scientists, small and medium-sized enterprises (SMEs) and consumers in addition to representations of various sectors of bio-based industries" (p. 60) work to innovate and inform a sustainable bio-economy.

Somewhat similarly, Hansen (2013)—based on a case-study of the Danish biofuels debate—demonstrates how distinct scientific perspectives on biofuels originate in different disciplines and can be affiliated with different political positions. The *reductionistic biorefinery perspective*, grounded in biochemistry and neighboring disciplines, works upward from the molecular level, and envisions positive synergies in the use of biomass. The *holistic bioscarcity perspective*, grounded in life-cycle analysis and ecology, works downward from global scope conditions, envisioning negative externalities from an increased reliance on biomass.[14] While the first, ideal-typically modern view sees biomass as an abundant resource, and industry as key driver of innovation, the second, ideal-typically postmodern view sees biomass as a scarce resource, emphasizing the ways private economic interests tend to overrule socially, environmentally, and technically optimal solutions. While the pro-biofuel coalition tends to emphasize "local growth," and the future competitiveness of Denmark in the emerging bio-economy, the skeptics are keener to couple the biofuel debate to questions of global responsibility and environmental justice. Supporters and opponents thus see different challenges and priorities (Hansen, 2013).

Critical scholarship has explored the philosophical foundations of the dominant, modernist understanding of the emerging bio-economy (see, for example, Birch, 2006; Birch et al., 2010;

Boyd et al., 2001; ETC Group, 2010; Richardson, 2012; Schmid et al., 2012). Frequently, these analyses seem embedded in what might be understood as a more postmodern worldview: these scholars criticize modernist assumptions and values (e.g., an ontologically and axiologically materialist orientation), underscore the ways in which the bio-economy as currently envisioned is a social construct designed to serve existing power-structures, and emphasize the marginalized interests of developing countries, small farmers, and nature itself.[15] According to Birch et al. (2010: 2898), the narrative of the bio-economy "reflects a specific techno-knowledge fix based on the harnessing and commodification of genetic and bio-molecular science in the intensification of natural productivity for commercial exploitation," especially through Intellectual Property rights. In this process, nature is not just a resource, which it has been since the industrial revolution, but is itself a factory and workforce. Capitalism is the end-goal and ultimate value behind (this view on) the bio-economy, while sustainability is mere means: "Life itself is characterized as capital, forever renewable and forever productive. Thus nature is meant to sustain capitalism through its own renewability" (Birch et al., 2010: 2902).

The traditional worldview appears less dominant in academic analyses of the stakeholder debate on the bio-economy, but plays a significant role in for example the debate on synthetic biology (Dragojlovic and Einsiedel, 2012) and medical biotechnology. Why this is so is an interesting question for further research. It may be attributed to the less religious and traditional nature of the societal and stakeholder-debate in Europe, combined with the influence of the Catholic church cautiously starting to embrace aspects of biotechnology when they can be argued to have social benefits (Meldolesi, 2011), gradually aligning their position with a more ideal-typically modern view.[16]

Table 2 summarizes how the IWF structures these data regarding views on biotechnology and the bio-economy, illuminating how the ideal-typical worldviews described in Table 1 may come to expression in these different positions. This serves to collate findings generated in earlier research, and clarifies how these may be understood as related to underlying worldview structures.

Discussion and conclusion

We have shown the IWF's use for analyzing societal responses to biotechnological innovation by illuminating the ideal-typical *traditional, modern*, and *postmodern* worldviews that appear to underlie the dominant positions. Based on literature reviews in the sections "Public perceptions of biotechnology" and "Stakeholder perspectives on the bio-economy," we argue that the IWF may be better able to account for diverging societal responses found in both literature around public perceptions of biotechnology and the stakeholder debate around the bio-economy, in comparison with for example CCT. This is so, in our eyes, because the more comprehensive operationalization of the concept of worldview used in the IWF allows one to take into account important aspects of worldviews (ignored in CCT), such as individuals' views on nature and the divine (ontology), science and authority (epistemology), what is valuable and moral in life (axiology), and the human–nature relationship (anthropology). The IWF's differentiation between traditional, modern, and postmodern worldviews may also be better able to explain the opposition to biotechnology found among both conservatives and progressives, which appears irreducible to CCT's distinction between hierarchical-individualists and egalitarian-communitarian worldviews.

We acknowledge that in social reality, traditional, modern, and postmodern worldview-positions tend to be more nuanced and diverse than these ideal-types describe them to be. There are both advantages and disadvantages to the use of heuristic, ideal-typical frameworks. While heuristics might lead us to overlook important phenomena or dynamics, they also help us to focus

Table 2. An overview of how the IWF can structure existing data and insights with respect to public and stakeholder views vis-à-vis biotechnology and the bio-economy.

	Traditional worldview	Modern worldview	Postmodern worldview
Ontology	Nature as God's creation that humans can use but not interfere in*	Nature as instrumental, resources for humanity**	Nature as complexly interrelated, somewhat fragile, set of systems* Emphasis on the cultural, emotional, and spiritual values of nature.
	Strongly religious. Belief in "natural order"*	Biomass seen as an abundant resource***	Biomass seen as a scarce resource ***
		Non-believers*	Non-believers*
Epistemology	Trust in: uncertain, medical profession, religious organizations*	Trust in: science and technology**/***	Trust in: NGO's, environmental, and consumer organizations.*/***
	Moral reasoning ("Faustian")*	Instrumental reasoning**/***	Pragmatic reasoning ("Frankensteinian")*
	Lower educated. Little knowledge about biotechnology*	Reductionistic biorefinery perspective; biochemistry and related disciplines***	Higher educated. More knowledge about biotechnology*
		Industrial perspective, genetic engineering and life-sciences oriented view****	Holistic bioscarcity perspective; life-cycle analysis, ecology, and environmental sciences**
		Reductionism, building-blocks, decomposability perspective****	Agro-ecological perspective, agro-ecological oriented view****
			Holism, systems-view, integrated perspective****
Axiology	Materialist value-orientation*	Materialist value-orientation.*	Post-materialist value-orientation*
		Competition, economic opportunities, and growth are emphasized.**/***/****	Global justice, social and environmental dimensions are emphasized.**/***/****
Anthropology	Human being as subject to God-created natural order*	By mastering nature, the human being can find freedom and well-being*/**	Human being as part of larger, complex natural systems*/**
	"Nature should be left alone"	"Humans are smarter than nature"	"Things in nature are more perfect than those made by humans"/"Nature should be left alone"
Societal vision/ Socio-technical imaginary	Technological intervention in nature a priori unacceptable. However, sometimes willing to accept risks for economic competitiveness.*	Technological intervention in nature is promising: "technological optimism" Environmental problems and other risks will be solved or managed through the further development of science and technology**	Technological intervention in nature not reprehensible per se. Emphasizes uncertainties and risks. Stresses the need for public consultation, regulation, and labeling of GM-foods. Skeptical about both risks and benefits of biotechnology*

Table 2. (Continued)

	Traditional worldview	Modern worldview	Postmodern worldview
	Political: center/right*	Key problem framing: Need to develop and implement alternatives to fossil fuels (e.g. in transport sector)***/****	Political: center/left*
		Industry is seen as key driver of innovation. Emphasis on economic potentials. Preference for market-based (incremental) solutions.**/***/****	Key problem framing: Need to foster long-term sustainable CO2 reductions in global perspective***/****
			Private economic interests are seen as tending to overrule the socially, environmentally, and technically optimal solutions. Preference for state-based (planning) solutions**/***/****

Sources:
*Nielsen et al. (2002).
**Hedlund-de Witt et al. (2014).
***Hansen (2013).
****Levidow et al. (2012a, 2012b), Schmid et al. (2012).
*****Peters et al. (2007).

analytic attention and yield insight. In our view, the worldview-framework succeeds in clarifying, structuring, and illuminating societal responses to biotechnology. Moreover, the IWF appears to support the interpretation and synthesis of different studies, placing them in a larger, social-cultural and historical context.

Ideal-typical worldviews may therefore inspire new research efforts into public perceptions, for example, by providing a blueprint for surveys or interviews, potentially functioning as a novel hypothesis (e.g. Hedlund-de Witt et al., 2014). The framework may serve interdisciplinary research efforts aimed at addressing "big challenges," connecting public responses to issues as diverse as climate change, vaccinations, and the future of agriculture, which are likely all shaped by the same underlying worldviews. The IWF may also support better understanding of the societal disagreements on these issues, as these are frequently based in fundamentally different understandings of reality.

Additionally, research into these worldviews may cultivate insight into the paradigmatic gaps existing particularly within the social sciences. As Victor (2015) has argued,

> because societies are complex and are in many ways harder to study than cells in a petri dish, the intellectual paradigms across most of the social sciences are weak. Beyond a few exceptions—such as mainstream economics—the major debates in social science are between paradigms rather than within them. […] Multiple competing paradigms make it hard to organize social-science knowledge or to determine which questions and methods are legitimate. (p. 28)

Exploring the worldviews associated with these competing paradigms may illuminate some of the vital debates in social science. Research efforts may benefit from an understanding of how "research worldviews" (Creswell and Plano Clark, 2011), coming to expression in guiding assumptions, theory, analyses, and methods, interact with the social scientific investigation of public understandings of science. Moreover, rather than exploring science-society issues in isolation, and from disparate disciplines, interdisciplinary research efforts aimed at understanding the larger patterns in public debates and trends may help connecting the different results and placing them into the larger historical-developmental trajectory of cultural epochs and changing worldviews in the West.

In terms of practical application, these worldviews may stimulate the crucial self-reflexivity among stakeholders and policy-makers, thereby supporting understanding of other viewpoints and more inclusive forms of debate and policy-making (De Witt and Hedlund, 2015, in press). Thus, governments and industries must also reflect on their own motives for engaging biotechnology and would benefit from making their worldviews transparent through systematic reflection (Osseweijer, 2006).[17] Because the "deficit model" of the public understanding of science is flawed on both conceptual and empirical grounds, different models aiding public engagement are needed. With a lens like the IWF, policy-makers are supported to consider a spectrum of perspectives that each have their own coherence and potential value. In practice, relating to them as such is much more fruitful than "right-wrong" polarization modes, and may lead to the use of a more comprehensive repertoire of methods and tools (De Boer et al., 2010).

Several authors speak of the emergence of an *integrative* or "integral" worldview in our contemporary cultural landscape, characterized by a tendency to synthesize perspectives that other worldviews consider polarized, such as rationality and spirituality, or individual and societal well-being (e.g. Benedikter and Molz, 2011; Hedlund-de Witt, 2014b; Van Egmond and De Vries, 2011). Although we have not included this worldview in our analysis (mainly for lack of available data), it may become of significance to approach a more constructive debate on the bio-economy—particularly because of its self-reflexivity and capacity to synthesize perspectives. Future research is needed to establish this; nonetheless, when worldview-positions are approached as each having valuable perspectives to offer, and synergies sought rather than polarizations reinforced, this will likely result in more inclusive, pluralistic, and constructive debates on these timely issues.

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Notes

1. Multiple studies show the complex ways that value predispositions or worldviews *interact* with scientific knowledge, and reveal the heuristic cues used to compute and evaluate that knowledge. For example, an experimental study of a large sample of American adults found that cultural cognition generates disagreement about the risks and benefits of the HPV vaccine through the mechanisms of biased assimilation, and the credibility heuristic (Kahan et al., 2010).

2. Currently, no published articles report these results. However, the website associated with CCT (http://www.culturalcognition.net) contains multiple blogposts describing the lack of cultural variance with respect to genetically modified foods. See, for example: http://www.culturalcognition.net/blog/2012/10/17/wanna-see-more-data-just-ask-episode-1-another-helping-of-gm.html.
3. Kahan et al. (2010) conducted a study that used the dispute over mandatory HPV vaccination to test the cultural cognition thesis. Although they found, as hypothesized, that hierarchy and individualism, particularly when combined, disposed subjects to be more concerned, and egalitarianism and communitarianism to be less concerned about the risks of HPV vaccination, the found effect was relatively modest in the absence of arguments about the risks and benefits of the vaccine.
4. See, for example, a recent article in the *New York Times*, reporting a measles outbreak, and discussing some of the culturally diverse reasons why individuals are resistant to vaccination: "Vaccine Critics Turn Defensive Over Measles," *New York Times*, 30 January 2015.
5. Several studies have criticized the explanatory power of cultural theory (on which CCT builds) on both conceptual and empirical grounds (e.g. Oltedal et al., 2004; Sjöberg, 1996).
6. While ontology, epistemology, and axiology can be considered primary worldview-aspects as they are essential components of a worldview, anthropology and societal vision could be considered secondary aspects as they constitute expressions or applications that flow from (or are subsets of) the primary aspects. Thus, other secondary aspects could be legitimately included, and some authors do so (e.g. Johnson et al., 2011). The choice to include the aspects of anthropology and societal vision in the IWF is based on their relevance for empirical research: anthropology stimulates researchers to investigate conceptions of the human being and human nature, while societal vision supports investigation of the societal and technological imaginaries and perspectives on the appropriate relationship between individual and society (Hedlund-de Witt, 2012).
7. These data were generated in 17 different European countries. While there was national variation owing to different cultural contexts, this was overshadowed by striking commonalties in the nature of skepticism across Europe. Of the 17 countries studied, Finland and Austria are the only nations for which the data did not fit this model. "Finland does not cluster with the other sceptic Scandinavian nations; instead it contains an unexpected number of optimists, analogously to the pro-development southern periphery of Europe. In stark contrast, the Austrians are not only sceptical, but extremely so" (Nielsen et al., 2002: 187).
8. These data have demonstrated that in advanced industrial, or post-industrial, societies, postmodern worldviews and values increasingly dominate the public's appreciation of a wide range of societal issues. This for example comes to expression in increasing questioning of the authority of science, appropriateness of technology and its associated risks, and in a growing appreciation for the idea of "naturalness" (see e.g. Inglehart and Welzel, 2005).
9. One study explored belief in God and its impact on approval of synthetic biology, finding that

   > among weak believers, belief in God appears to be associated with the increased availability and accessibility of the idea that genetic manipulation interferes with nature. Strong believers, in contrast, appear to also engage in an explicitly theological evaluation of synthetic biology, with opposition to synthetic biology resulting from the perception that the creation of new types of organisms encroaches on a domain of activity (creation) that has traditionally been considered to be a divine prerogative. (Dragojlovic and Einsiedel, 2012: 869)

10. One distinguishing feature of the modern relative to the traditional worldview is a belief in progress, the idea that history will unfold into an open, possibly limitless future, rather than in decline from a "Golden Age" or even expectation of the imminent end of the world (Edgar, 2008). Empirical research (Dragojlovic and Einsiedel, 2013) shows that a "declinist worldview" (measured with statements like "modern civilization has reached its peak and is in decline") reduces support for life-extending biotechnologies even when general attitudes toward science and technology are controlled for. Generally speaking, the ideal-typical traditional worldview is more inclined to be critical of development and change (Hedlund-de Witt, 2014b).

11. This survey found that large majorities worldwide believe that the benefits of modern technology outweigh the risks.
12. The deficit-model refers to the idea that acceptance of newly emerging technologies can be achieved through a more scientifically informed public (Michael, 2002; Sturgis and Allum, 2004). As the studies reported above show, this is out of step with the empirical evidence. Moreover, as many have argued, this model reveals a perspective in which "winning over the public is often viewed as an exercise in bureaucratic rationality, with contempt for public perceptions of risk, and an assumption that the public is ignorant, irrational, or even hysterical when it comes to certain technologies" (Mehta and Gair, 2001: 242). Uncritical technological optimism has also been found to be related to less care for the environment, and less sustainable lifestyles (Hedlund-de Witt et al., 2014), and may thus not offer a sustainable basis for newly emerging biotechnologies.
13. Tarakeshwar et al. (2001) empirically demonstrated that belief in the sacredness of nature was also associated with greater pro-environmental beliefs and willingness to invest personal funds in the environment, while greater theologically conservative views were associated with a lower care for the environment. These findings underscore how the same (e.g. traditional) worldview may come to expression differently, depending on the beliefs espoused (e.g. theistic sanctification versus theological conservatism).
14. Among the proponents of biofuels in Denmark are the biotechnology industry, Denmark's biggest energy company, and the dominant agricultural sector interest organization; the biofuel skeptical coalition comprises environmental NGOs and the Danish Energy Agency.
15. Although these authors may not necessarily identify with the label postmodern, we use the concept broadly, referring to a set of values and assumptions that express a more popular understanding of the philosophical ideas of the academic, literary, and artistic postmodern movements. Doing this, we follow several authors who have linked the intellectual orientations of the postmodern intelligentsia with the widespread emergence of values and orientations that reflect similar commitments to relativism, pluralism, diversity, other forms of knowing, self-expression, post-materialist values, a generally critical attitude toward modern notions of progress, science and technology, and an emphasis on the emancipation of marginalized groups (e.g. Benedikter and Molz, 2011; Butler, 2002; Inglehart, 1997) .
16. The debate on stem cell research in the United States provides an example of the clash between traditional and modern worldviews with respect to medical biotechnology. While the scientific community has often emphasized the potential of stem cell research for treating numerous health problems, religious conservatives argue against this kind of research on religious and ideological grounds (e.g. Ho et al., 2008; Nisbet, 2005). As research (Ho et al., 2008) has shown, public attitudes toward embryonic stem cell research are profoundly informed by value predispositions, with religiosity and (conservative) ideology (associated with our traditional ideal-type) showing robust negative relationships, and deference to scientific authority (associated with our modern ideal-type) displaying a strong positive relationship with support for embryonic stem cell research.
17. Policy-makers could inquire into their own predominant worldview-structure, reflecting on their answers to the worldview-questions discussed in the "Methodology" section, or reading through the different worldview-descriptions, noting patterns of resonance or dissonance between these and their own assumptions and values. Including the creative arts to communicate about these concepts in imaginative, compelling, and novel ways may be essential to create this kind of reflexivity.

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Author biographies

Annick De Witt is a post-doctoral research fellow interested in worldviews and the transformation to (more) sustainable societies, including public perceptions of global issues like climate, energy, food, and biotechnology.

Patricia Osseweijer is a full professor "Biotechnology and Society." Her research focuses on the role of social issues, values, and ethics in the development of a bio-based economy; integral sustainability impact assessments in bio-based innovation; and communication with stakeholders and publics.

Robin Pierce is senior Associate of Law and Ethics at Harvard Law School. Her main focus is on policy, regulatory, and ethical issues in the integration of advances in science and technology.